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Does Sedimentary Phosphate Reflect Sediment Maturity?

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Does Phosphate Level Reflect Sediment Maturity?

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Abstract

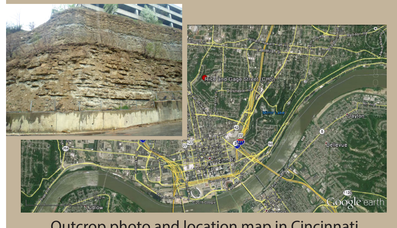
Despite the critical role of this dwindling resource in modern agriculture, the origin of sedimentary phosphate (the process of "phosphogenesis") is not well understood. Based on the idea that oceanic chemistry is the primary driver of phosphogenesis, widespread phosphate deposits have been used as evidence of periods of unusual marine chemistry or circulation patterns. This study will test an alternative hypothesis, that slow sedimentation rates coupled with episodic high-energy events under otherwise normal marine conditions led to phosphogenesis in the Ordovician (450 million years old) of the Cincinnati region. These Cincinnatian limestones contain different amounts of phosphate. If the hypothesis is correct, then the amount of phosphate in the limestones should correlate to the amount of reworking that the limestone had experienced before final burial.

By microscopic study of the rocks in thin sections (thin slices of rock glued to microscope slides), the amount of phosphate can be quantified and the proxies for "sediment maturity" can be ranked or quantified. These proxies include: 1) condition of fossil seashells (breakage, abrasion, borings), 2) size distributions of shell particles, 3) the species of shell fossils present (indicating both ecology and preservation), and 4) relative abundance of shells, mud, and crystal-filled spaces (often used to classify limestones).

Sixty thin sections from a locality in Cincinnati (an old quarry face at Rice and Gage Streets, Cincinnati, Ohio) have been made and will be used for this preliminary study. For each slide, the amount of phosphate, shell breakage, abrasion, and boring will be estimated or ranked, species present will be measured, and relative abundance or mud, shells, and void space will be estimated. These measured of sediment maturity will be plotted against amount of phosphate to test for correlation.

Introduction

Sedimentary phosphate is the principle source of phosphorous in modern fertilizers, yet phosphogenesis is not fully understood, because phosphate deposition is observed in a very narrow set of modern environments. There are two competing hypotheses to explain large phosphorite deposits: 1) that unusual chemical conditions,-such as oceanic anoxia, lead to ***rapid*** phosphate deposition.; or 2) that low sedimentation rates and multiple reworking events led to long-term concentration of ***normal (slow)*** phosphate accumulations. This study tests the second hypothesis by correlating proxies for slow sedimentation with the concentration of phosphate in the rock.



Outcrop photo and location map in Cincinnati

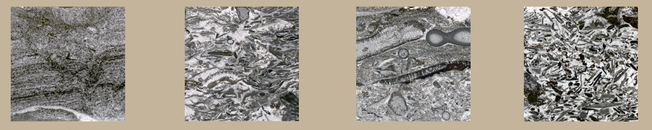
Phosphatized fossils

Methods

More than sixty thin sections were made from different strata in a succession exposed in a quarry in Cincinnati. These are made by gluing polished slices of rock to glass and grinding the rock very thin for microscopic observation. The thin sections were scanned at 3200 dpi and these images were cropped 71 2 cm X 2 cm square images to be ranked and categorized by 1) phosphate concentration, 2) carbonate rock type, and 3) fossil fragmentation. Contingency tables were generated from this data and tested against random relationships using Chi^2.

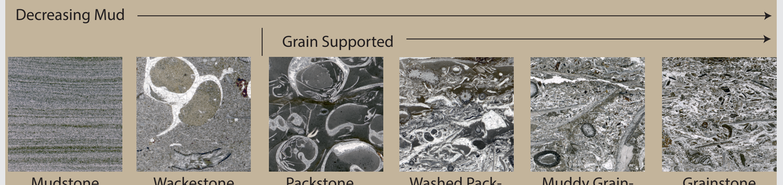
Traits observed

Phosphate grain density classes (visually estimated)



Type of calcium carbonate sediment:

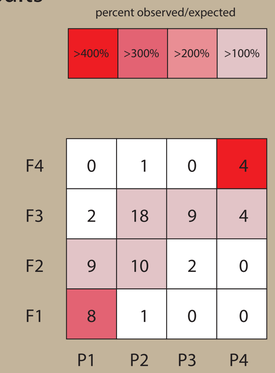
Arranged in order of increasing energy or sediment maturity, as indicated by removal of mud.



Shell fragmentation:

Shell fragmentation should increase with longer seafloor exposure and repeated reworking.

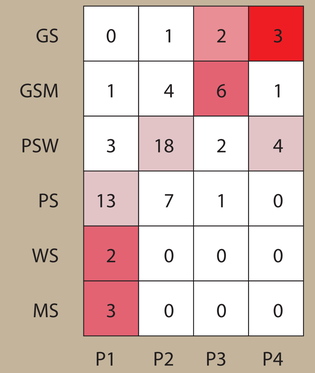
Results



Phosphate level vs. degree of fragmentation contingency table

Chi squared value of 55.5843
0.00001 value of 39.3407 with 9 degrees of freedom.

Increasing levels of phosphate correspond to increasing degrees of fragmentation.



Phosphate level vs. rock type contingency table

Chi squared value of 54.1667
0.00001 value of 50.493 with 15 degrees of freedom.

Increasing levels of phosphate correspond to "cleaner" sediments (smaller amounts of mud).

Conclusions

This study suggests a strong relationship between the amount of phosphate in the rock and the degree of reworking. Evidence of reworking of the sediments include higher amounts of fragmentation and less amounts of mud. When arranged in stratigraphic order, the amount of phosphate observed in the thin sections does not change monotonically with time. However, periods of higher amounts of phosphate tend to correspond to higher amounts of breakage and crystallization (less mud). To continue this research, further data will be gathered from more thin sections from similar localities and develop more quantitative measures.

Acknowledgements

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